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(54) PHOTOVOLTAIC DEVICE WITH DECREASED GRIDLINE SHADING AND METHOD FOR ITS MANUFACTURE

PHOTOVOLTAISCHE ANORDNUNG MIT ERNIEDRIGTER SCHATTENBILDUNG DURCH DAS KONTAKTGITTER UND HERSTELLUNGSMETHODE

DISPOSITIF PHOTOVOLTAIQUE REDUISANT LES OMBRES DES BARREAUX DE GRILLE ET PROCEDE DE FABRICATION DU DISPOSITIF

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Description

Field of the Invention

This invention relates generally to photovoltaic devices. More specifically, the invention relates to a method of manufacturing photovoltaic devices with increased efficiency resultant from the minimization of shading effects caused by current-collecting grids.

Background of the Invention

Photovoltaic energy is becoming a very significant power source for several reasons. Fossil fuels are becoming scarcer, and hence more expensive, every day. Furthermore, the burning of fossil fuels releases pollutants, including greenhouse gases which contribute to problems of global warming. Also, recent events have raised questions as to the safety and cost-effectiveness of nuclear power. For these reasons, traditional energy sources have become far less attractive. Photovoltaic energy, on the other hand, is inherently non-polluting, safe and silent. In addition, recent advances in photovoltaic technology have significantly increased the efficiency, and decreased the cost, of such devices.

For example, it is now possible to manufacture large area silicon and/or germanium alloy materials which manifest electrical, optical, chemical, and physical properties equivalent, and in many instances superior to, their single crystalline counterparts. Layers of such alloys can be economically deposited at high speed over relatively large areas and in a variety of stacked configurations. Such alloys readily lend themselves to the manufacture of low cost photovoltaic devices. Examples of particular fluorinated semiconductor alloy materials having significant utility in fabrication of photovoltaic devices are described in U.S. Patent No. 4,226,898 and U.S. Patent No. 4,217,374, both invented by Ovshinsky et al, the disclosures of which are incorporated herein by reference.

In a typical large area photovoltaic device, a number of current-collecting structures are employed to convey photo-generated current to a terminal or other collection point. As used herein, these various structures will be referred to as "current-collecting grids" or "gridlines," these terms being understood to include both grids and bus bars as well as any other opaque conductors associated with the light incident side of photovoltaic devices. Use of current-collecting grids is necessary to withdraw power from the photovoltaic device; however, these grids are typically made of high electrical conductivity material such as deposited metal patterns, adhesively adhered metal tapes, metal-containing pastes, metallic inks or plated layers and are quite opaque. The gridlines shade underlying portions of the photovoltaic device thereby preventing it from generating power. Clearly, the gridlines are needed to allow for the efficient withdrawal of photo-generated current, but their presence also detracts from the overall efficiency of the cell. The lines can be made smaller; however, this increases their electrical resistance and thereby tends to decrease cell efficiency. Under the constraints of the prior art, a designer of photovoltaic devices is caught in a dilemma of having to balance the electrical resistance of the cell versus the amount of active area presented for illumination.

In some instances, prior art cells relied upon the use of relatively thin deposits of high conductivity metals such as pure gold, silver or copper to provide high conductivity, relatively small area gridlines. However, such approaches require the use of sophisticated photolithographic techniques for patterning the gridlines. Additionally, the length of such thin gridlines was limited by the need to avoid high resistivity; consequently, this approach is limited in size and is quite expensive. Lower cost, easier to apply gridlines prepared from paste or ink material are quite desirable; however, they are of lower conductivity and hence must be made fairly thick and wide to achieve sufficient current carrying capabilities. Such materials were not heretofore practical since the gridlines they provide create a high level of shading. What is needed is a method and structure which permits the use of relatively wide gridline patterns, while minimizing shading from those gridlines.

Various attempts have been implemented in the prior art to employ optical systems to concentrate light in areas remote from gridlines. Such approaches involve the use of prismatic arrays and the like. These arrays are typically supported in a spaced-apart relationship with the photovoltaic device or they are adhesively affixed to the light incident side of the device and, when properly aligned, redirect light falling in the region of gridlines to grid-free portions of the device. This technology is typically employed in conjunction with concentrator cells. An overview of this technology is presented by Zhao et al in a paper entitled "Improvements in Silicon Concentrator Cells," published in the Proceedings of the 4th International Photovoltaic Science and Engineering Conference, Sydney, Australia, February 14-17, 1989, Vol. 2, p.581. Use of a Fresnel, lenticular concentrator is also disclosed in U.S. Patent No. 4,711,972. US-A-4 379 202 discloses photovoltaic cells each provided with a transparent cover having a front surface shaped in the form of a series of similar convex cylindrical segments to direct radiation which would otherwise be incident upon gridlines so as to be incident on an unobstructed portion and thus reduce shadowing losses. The cover may be fabricated by pressing or extrusion. These prior art approaches employ fairly precise lenses which must either be adhesively affixed to a photovoltaic cell or mounted in a support frame spaced apart from the photovoltaic cell in proper alignment. Use of lenses of this type requires skill in placement and affixation. If the lenses are misaligned, they will be worse than useless since they will direct light to, rather than away from, the gridlines. In use, conditions such as ambient heat and/or mechanical impact can misalign the

lens element, thereby decreasing cell efficiency.

What is needed is a photovoltaic device having decreased shading from gridlines, which device does not necessitate the precise placement and adhesive affixation of a separate lens element. The present invention provides for an improved photovoltaic cell having decreased shading as well as for a simple method of manufacturing that cell. According to the present invention, light-directing optics are formed integral with the photovoltaic device as a step in its manufacture. This results in a low cost, high efficiency, high accuracy process for the manufacture of photovoltaic devices having increased efficiencies. The method of the present invention may be adapted for the manufacture of single cells as well as for the manufacture of modules comprised of interconnected cells. These and other advantages of the present invention will be readily apparent from the drawings, discussion and description which follow.

Applied Optics, Vol. 26, No. 17, 1st September 1987, Page 3594-3599 discloses the use of an embossing die to manufacture a lens array forming part of an avalanche photodiode array. The lens array is formed by first forming an array of narrow-topped prisms in silicon using preferential etching techniques on [100]-oriented single-crystal silicon. This pattern is then vacuum pressed into the glass to form an array of trapezoids. The array of trapezoids is then polished using a long-napped polishing cloth to round the trapezoids into approximate cylinders.

Summary of the Invention

There is disclosed herein a method of manufacturing a photovoltaic device having decreased shading from collector gridlines. The method includes the steps of providing a photovoltaic cell which includes a bottom electrode layer, a photovoltaic body disposed atop the bottom electrode layer and a top electrode layer disposed atop the photovoltaic body. The photovoltaic cell further includes an electrically-conductive, current-collecting gridline associated in electrical communication with the top electrode. The method includes the further step of disposing a layer of embossible, transparent-encapsulating material atop the top electrode layer, providing an embossing die which includes at least one groove-forming element thereon and aligning the die with the photovoltaic cell so that the groove-forming element is in registry with at least a portion of the length of the gridline and in contact with the layer of encapsulating material. The method further includes the step of compressing the embossing die and photovoltaic cell so as to emboss a groove into the encapsulant layer and the final step of removing the embossing die. In this manner, there is provided a photovoltaic cell having a groove integral with the encapsulating layer. The groove is operable to direct incident illumination away from the gridline so as to decrease shading effects caused by it. In particular embodiments, the transparent embossible layer is a layer of synthetic organic polymer material such as ethylene vinyl acetate, polytetrafluoroethylene, polyvinyl fluoride, polyvinyl acetate, polystyrene, polyurethane and combinations thereof. In particular embodiments, a two step process is carried out wherein the cell and encapsulant are first laminated to provide a self-supporting structure which is subsequently embossed (and optionally cross-linked) in a second step. In some embodiments, the embossing die is heated and compression is carried out at pressures of approximately one atmosphere. In a particular embodiment, the layer of transparent polymeric material is a layer of thermally cross-linkable material and it becomes hardened while the groove is embossed.

The method of the present invention may be adapted to the manufacture of large area modules comprised of a plurality of interconnected cells and includes the initial step of disposing a plurality of photovoltaic cells onto a support member and encapsulating those cells with a layer of transparent encapsulant material. The method includes a further step of providing a plurality of embossing dies, each including at least one groove-forming element, as well as the steps of aligning the dies with corresponding photovoltaic cells and compressing the dies and cells. Alignment may be accomplished by punching alignment holes into the support portion of the module and providing the dies with pins configured to fit in the holes. In this manner, the dies may be aligned properly with regard to individual strip cells thereby eliminating problems resulting from slight misalignment between individual cells.

The present invention further includes an improved photovoltaic cell manufactured according to the method and including an optical element formed integral with the encapsulant layer.

Brief Description of the Drawings

FIGURE 1 is a cross-sectional view of a portion of a photovoltaic cell of the prior art illustrating the problem of gridline shading;

FIGURE 2 is a cross section of a portion of a photovoltaic cell manufactured in accordance with the present invention and illustrating the manner in which gridline shading is reduced.

FIGURE 3 is a cross-sectional view of one embossing die which may be utilized in the practice of the present invention;

FIGURE 4 is a top plan view of a large area photovoltaic module manufactured in accordance with the present invention;

FIGURE 5 is a top plan view of an embossing die of the type utilized to manufacture the module of FIGURE 4;

FIGURE 6 is a cross-sectional view of a portion of a photovoltaic cell illustrating another configuration of a groove;

FIGURE 7A is a cross-sectional view of a photo-

voltaic cell illustrating one particular configuration of a groove structured in accordance with the present invention; and

FIGURE 7B is a cross-sectional view of the cell of FIGURE 7A, illuminated at an oblique angle.

Detailed Description of the Invention

Referring now to Figure 1, there is shown a cross-sectional view of a portion of a photovoltaic cell of the prior art illustrating the problem of gridline shading. The cell includes a substrate 10, which in this instance is a metallic substrate which also functions as a bottom electrode layer. Disposed immediately atop the electrically-conductive substrate 10 is a body of photovoltaic material 12 and immediately thereatop on the light incident side of the photovoltaic body 12, is a top electrode layer 14. The top electrode layer 14 is most preferably fabricated from a transparent material so as to permit passage of light therethrough. Associated with the top electrode layer 14 is a gridline 16 which operates to collect current from the top electrode layer 14 and carry it to a bus bar or other terminal. The top, i.e. light incident, surface of the photovoltaic device is protected by a layer of transparent, encapsulant material 18.

There are a great variety of materials which may be utilized to manufacture the photovoltaic devices according to the present invention. The bottom electrode layer is fabricated from an electrically-conductive material and as noted hereinabove, may also function as a support substrate for the device. Toward that end, one preferred material is stainless steel of approximately 0.2mm (8 mils) thickness. Other substrates include electrically-insulating materials such as polymeric bodies, glass or ceramics and, in such instances, the electrode layer will be deposited thereatop. The photovoltaic body 12, as is well known to those of skill in the art, operates to absorb incident photons and to generate electron-hole pairs in response thereto, and to separate the members of these pairs and direct them to the respective electrodes 10,14 of the cell. There are a great variety of photovoltaic materials known to those of skill in the art and the present invention is not limited to any one such material. Among some of the preferred materials are the thin film materials such as the fluorinated silicon and germanium alloys referred to hereinabove as well as cadmium telluride, gallium arsenide, copper indium diselenide, single crystal silicon and the like. In one particularly preferred embodiment, the photovoltaic body comprises at least one triad of silicon alloy material which includes a layer of intrinsic material 12a interposed between N-type 12b and P-type 12c alloy materials. In one preferred embodiment, at least one of the N-type 12b and P-type layers 12c is a microcrystalline layer, preferably the layer proximate the light incident side of the photovoltaic device. In some instances, a number of triads of N-I-P (or P-I-N) type materials are stacked one atop another to provide for enhanced efficiency and sensitivity.

The top electrode layer 14, as noted hereinabove, is preferably a transparent body and there are available a number of highly degenerate semiconductors such as indium-tin oxide and the like which may be employed as top electrode layers. The gridline 16 is preferably fabricated from an electrically-conductive ink or paste or it may be a metallic body adhered to the top electrode layer. In some instances, the gridline 16 is placed beneath or embedded within the top electrode layer 14. For this reason, and within the context of the present invention, the gridline 16 is described as being electrically associated with the top electrode layer 14. The layer of encapsulant material 18 protects the components of the photovoltaic cell from the ambient environment and from mechanical damage. The encapsulant layer 18 is preferably fabricated from a material which is highly transparent and inert. Organic polymers comprise the most preferred materials for this layer and ethylene vinyl acetate (EVA) is one particularly preferred material. Cross-linkable ethylene vinyl acetate having particular utility in the present invention is sold by the Du Pont de Nemours, E.I. & Company. Other preferred materials include fluorocarbon polymers, polyurethane, polystyrene, and polyvinyl acetate as well as various silicon compounds. In some instances, a bi-layered structure of fluoropolymer/EVA is employed.

Figure 1 illustrates the manner in which prior art photovoltaic cells suffered from problems of gridline shading. As will be noted, a photon flux 20 is shown as incident upon the device. Those photons which strike the gridline 16 are absorbed, or in some instances reflected, and hence not available to penetrate the photovoltaic body and generate charge carriers. These photons effectively represent a loss in the efficiency of the cell.

Referring now to Figure 2, there is shown a photovoltaic device generally similar to that of Figure 1, but comprising a transparent encapsulating layer 18' configured to include an integral optical element in a form of a groove disposed in the region of the gridline 16. The particularly configured transparent encapsulant layer 18' operates to diffract incident light 20 away from the gridline 16 and into the photovoltaic body 12. In this manner, shading losses occasioned by the presence of the gridlines 16 are minimized. As a consequence, gridlines may be made wider and hence longer and the cell size may be greatly increased.

Since the light-directing optical element of the present invention is provided integral with the transparent encapsulating layer 18', problems attendant upon the alignment and adherence of a separate optical element are eliminated. In accordance with the present invention, the grooved optical element is formed in the layer only after the encapsulation of the photovoltaic cell, and problems occasioned by the misalignment and/or detachment of a separate optical element are eliminated.

In the most preferred embodiment of the present invention, the grooved optical element is formed in the transparent encapsulating layer by an embossing process employing a die generally similar to that depicted to that in cross section in Figure 3. The die 22 of Figure 3 is preferably fabricated from a metal, ceramic or similar durable material having good heat transfer characteristics and includes a number of groove-forming projections 24 upon the face thereof. The spacing between adjoining groove-forming portions is selected to correspond to the spacing between grid fingers in a given configuration of photovoltaic device.

In accordance with the method of the present invention, a photovoltaic cell is first provided with a top encapsulant layer, such as the polymeric layer 18 described with reference to Figure 1. This layer is affixed by a laminating process carried out a moderate temperature so as to avoid cross-linking the encapsulant. The structure thus produced is sufficiently rigid to withstand subsequent handling and processing. In the second step, an embossing die generally similar to that of Figure 3 is aligned with the photovoltaic cell so that the groove-forming portions 24 thereof are aligned substantially with the grid fingers. At that time, the die 22 and cell are compressed so as to emboss the groove pattern into the transparent layer to produce a structure similar to layer 18' of Figure 2. The process may be facilitated by heating of the embossing die 22. In general, any combination of parameters which will produce a relatively permanent deformation of the encapsulating layer may be employed. However, it has been found most preferable in accord with the present invention to utilize an encapsulant material which is cross-linkable, i.e. a material which cross links and hardens at elevated temperatures to provide a permanent structure. The aforementioned EVA polymer fulfills these criteria since it initially softens at a temperature of approximately 60°C and subsequently cross links to form a hard layer at a temperature of approximately 140°C. These properties allow the groove-forming elements to initially penetrate and shape the layer, and subsequently harden it to cause it to retain its shape and the optical characteristics produced thereby. In a typical process employing an EVA layer, the die is heated to approximately 150°C and a pressure of one atmosphere is maintained on the die for approximately 30 minutes. In some instances, the initial lamination and the embossing may be carried out in a one-step concerted process.

It is frequently desirable to interconnect smaller area photovoltaic cells into a large area module so as to provide an increased voltage and/or power-producing capability. The present invention may be readily adapted for use in connection with the production of large area modules. Referring now to Figure 4, there is shown a large area photovoltaic module 30 comprised of four individual photovoltaic cells 32,34,36,38 disposed upon a support substrate 40. The individual cells 32,34,36,38 each include a plurality of gridlines 16 formed thereupon. Each gridline is in electrical communication with a bus bar 42 disposed on the periphery of the cell. The individual cells 32,34,36,38 of the module 30 of Figure 4 are interconnected in a series relationship by means of electrically-conductive jumpers 44 interconnecting the bus bars 42 of a first cell with the bottom electrode of an adjacent cell. The module further includes a pair of output terminals 46,48 electrically connected to the bus bar 42 of cell 38 and to the bottom electrode of cell 32. At this stage, the individual cells are laminated into a single large-area device as noted above, by moderate heat and compression (typically 60°C when EVA is the laminant). It will be noted from the figure that the individual cells 32,34,36,38 are not all evenly aligned on the substrate 40. The present invention provides for a method of embossing the groove pattern into the cells without regard to any alignment requirements between the various cells and thereby simplifies module manufacture. It will be noted from the figure that each of the cells 32,34,36,38 has four alignment holes 50a,50b,50c,50d associated therewith. After the initial lamination, these holes are punched through the substrate 40 and are oriented with regard to the orientation of the individual cell and serve as alignment guides for placement of the embossing die. Punching of the alignment holes 50, may be accomplished by the use of a template having indicia which are aligned with the grid pattern or other feature of the cell and which serve to properly position the punches.

Referring now to Figure 5 there is shown a top plan view of an embossing die 52 generally similar to that illustrated in Figure 3 but further including four alignment pins 54 thereupon. These pins, when placed into the corresponding pin holes in the module, serve to align the groove-forming elements 24 of the die 52 with the gridlines 16. When the module is to be completed, individual dies are placed in registry with each cell through the use of the alignment pins 54 and the entire assembly is compressed, preferably with heating, to effect groove formation.

While the foregoing figures depicted the grooves as being straight-sided grooves having flattened areas therebetween, the present invention may be practiced with other groove structures. For example, Figure 6 depicts a curved groove structure having rounded, lenticular portions 60 between adjoining grid fingers 16. Many other variations will be readily apparent to one of skill in the art. For example, by selecting the width and angle of the grooves, the acceptance of illumination may be varied to account for seasonal variations in the direction of insolation. Wider grooves will tend to gather more light; however, a groove which is too wide can cause redirection of light onto adjoining grid fingers. One of skill in the art could readily control the parameters of finger spacing and groove shapes so as to achieve a minimization of shading and a maximization of power output.

Figures 7A and 7B illustrate one particular configu-

ration of groove width and angle as optimized to accommodate the varying angles of insolation. Figure 7A depicts one particular configuration of photovoltaic device structured in accordance with the principles of the present invention. The device of Figure 7A includes a top encapsulating layer 18, generally similar to those previously described and being approximately 0.95 millimeters in thickness. The device further includes a gridline 16 which is 0.3 millimeters in width. The groove formed in the encapsulant layer forms an angle "A" of approximately 42° with the perpendicular bisector of the groove indicated by the dashed line. The width of the groove as measured across the top of the layer 18 is approximately 0.8 millimeters.

As illustrated in Figure 7A, a flux of light 20 is incident upon the device in a direction perpendicular to the top surface of the device. As will be noted, the light is directed away from the gridline 16. Figure 7B is a depiction of the same photovoltaic device having light flux 20 incident at an angle of approximately 70° (20° off the perpendicular) to the surface thereof. It will be noted that the particular configuration of groove still functions to greatly minimize shading. Only a small portion of the light is actually incident upon the gridline 16.

The particular angle and width of a groove will depend upon the thickness of the underlying layer and the width of the gridline. Calculation of groove configuration may be readily undertaken by one of skill in the art employing basic principles of optics. The foregoing drawings and description are illustrative of particular embodiments of the present invention and are not limitations upon the practice thereof. The following claims define the scope of the invention.

Claims

1. A method of manufacturing a photovoltaic device having decreased shading of incident illumination from collector gridlines, said method comprising the steps of:

   providing a photovoltaic cell, said cell including a bottom electrode layer, a photovoltaic body disposed atop the bottom electrode layer, a top electrode layer disposed atop the photovoltaic body and an electrically-conductive, current-collecting gridline in electrical communication with said top electrode layer;
   disposing a layer of embossable, transparent, organic, polymeric, encapsulating material directly atop the top electrode layer;
   providing an embossing die, said die including at least one groove forming element;
   aligning the embossing die with the photovoltaic cell so that the groove forming element thereof is in registry with at least a portion of the length of the gridline and in contact with the layer of polymeric encapsulating material; and
   compressing the embossing die and photovoltaic cell so as to emboss a groove into the layer of encapsulating material; and
   removing the embossing die, whereby there is provided a photovoltaic cell having a groove integral with the encapsulant layer and in registry with said portion of said gridline, said groove directing incident illumination away from the gridline so as to decrease the shading effects thereof.

2. A method as in claim 1, wherein the step of disposing a layer of encapsulating material atop the top electrode layer includes the further step of laminating said layer to the top electrode layer and wherein the steps of aligning and compressing are carried out after said laminating step.

3. A method as in claim 1, wherein the step of disposing said layer of organic polymeric material includes a further step of selecting said material from the group consisting of ethylene vinyl acetate, polytetrafluoroethylene, polyvinyl fluoride, polyvinyl acetate, polystyrene, polyurethane, and combinations thereof.

4. A method as in claim 1, wherein said polymeric material is a thermally cross-linkable material.

5. A method as in claim 1, including the further step of heating said embossing die.

6. A method as in claim 5, wherein the step of heating said die comprises heating to a temperature of approximately 150°C.

7. A method as in claim 1, wherein the step of compressing said photovoltaic cell and die comprises compressing said cell and die at a pressure of approximately 1,01 10^5 Pa (one atmosphere).

8. A method as in claim 1, wherein the step of compressing said photovoltaic cell and die further comprises maintaining said cell and die under compression for approximately 30 minutes.

9. A method as in claim 1, wherein the step of providing a photovoltaic cell comprises providing a photovoltaic cell having a photovoltaic body including at least one layer of a fluorinated, silicon alloy material.

10. A method of manufacturing a large area photovoltaic module, said method comprising the steps of:

    providing a plurality of photovoltaic cells, each cell including a bottom electrode member, a

photovoltaic body disposed in electrical communication with the bottom electrode, a top electrode disposed atop the photovoltaic body, and at least one electrically-conductive gridline associated in electrical communication with the top electrode;
disposing said plurality of cells on a support member in an electrically interconnected relationship;
disposing a layer of transparent, organic, polymeric, encapsulant material directly atop the top electrode and said at least one gridline of each of the photovoltaic cells;
laminating said encapsulant material onto said cells so as to provide a self-supporting assembly;
providing a plurality of embossing dies, each die including at least one groove-forming element;
aligning each of said plurality of dies with a corresponding one of said photovoltaic cells so that the groove-forming element thereof is in registry with at least a portion of the length of one of said at least one gridline; and
compressing said dies and laminated assembly of photovoltaic cells whereby said dies form grooves in the transparent encapsulating layer in the regions of the gridlines so as to provide a light-directing optical element integral with said layer of encapsulant material decreasing gridline shading.

11. A method as in claim 10, wherein the step of aligning each of said dies with a corresponding one of said cells comprises:

providing alignment pins on each of said plurality of dies;
providing corresponding alignment pin holes in said support member; and
placing said alignment pins in the said alignment pin holes.

12. A method as in claim 10, wherein the step of disposing said cells on said support member in an electrically interconnected relationship comprises the step of interconnecting said cells in a series electrical relationship.

13. A method as in claim 10, wherein the step of providing a layer of transparent, encapsulant material comprises selecting said material from the group consisting of: ethylene vinyl acetate, poly tetrafluoroethylene, polyvinyl fluoride, polyurethane and combinations thereof.

14. A method as in claim 10, including the further step of heating said plurality of dies.

Patentansprüche

1. Verfahren zur Herstellung einer photo-voltaischen Anordnung, die eine verminderte Schattierung der einfallenden Beleuchtung durch die Kollektor-Gitterlinien hat, wobei das Verfahren die folgenden Schritte umfaßt:

Bereitstellen einer Sperrschichtzelle, wobei diese Zelle eine Bodenelektrodenschicht, einen photo-voltaischen Körper, der oben auf der Bodenelektrodenschicht angeordnet ist, eine obere Elektrodenschicht, die oben auf dem photo-voltaischen Körper angeordnet ist, und eine elektrisch leitende, stromsammelnde Gitterlinie in elektrischer Verbindung mit der oberen Elektrodenschicht hat:
Anordnen einer Schicht aus einem prägefähigen, transparenten, organischen, polymeren Vergußmaterial direkt oben auf der oberen Elektrodenschicht;
Bereitstellen einer Prägeform, wobei die Form wenigstens ein rillenbildendes Element einschließt;
Ausrichten der Prägeform mit der Sperrschichtzelle, so daß deren rillenbildendes Element mit wenigstens einem Abschnitt der Länge der Gitterlinie im Eingriff und mit der Schicht des polymeren Vergußmaterials in Kontakt ist, und
Zusammendrücken der Prägeform und der Sperrschichtzelle, um so eine Rille in die Schicht des Vergußmaterials zu prägen: und
Abnehmen der Prägeform, wodurch eine Sperrschichtzelle geschaffen wird, die integral mit der Schicht des Vergußmaterials und im Eingriff mit dem genannten Abschnitt der Gitterlinie eine Rille hat, wobei die Rille einfallende Beleuchtung weg von der Gitterlinie lenkt, um so deren schattierende Wirkung zu verringern.

2. Verfahren nach Anspruch 1, bei dem der Schritt des Anordnens einer Schicht von Vergußmaterial oben auf der oberen Elektrodenschicht den weiteren Schritt des Laminierens dieser Schicht auf die obere Elektrodenschicht einschließt und bei dem die Schritte des Ausrichtens und des Zusammendrükkens nach diesem Laminierungsschritt ausgeführt werden.

3. Verfahren nach Anspruch 1. bei dem der Schritt des Anordnens der Schicht aus organischem, polymeren Material den weiteren Schritt einschließt, dieses Material aus der Gruppe auszuwählen, die aus Ethylenvinylacetat, Polytetrafluorethylen, Polyvinylfluorid. Polyvinylacetat, Polystyrol, Polyurethan und deren Kombinationen besteht.

4. Verfahren nach Anspruch 1, bei dem das polymere

Material ein thermisch vernetzbares Material ist.

5. Verfahren nach Anspruch 1, einschließlich des weiteren Schritts des Erwärmens der Prägeform.

6. Verfahren nach Anspruch 5, bei dem der Schritt des Erwärmens der Form das Erwärmen auf eine Temperatur von annähernd 150°C umfaßt.

7. Verfahren nach Anspruch 1, bei dem der Schritt des Zusammendrückens der Sperrschichtzelle und der Form das Zusammendrücken der Zelle und der Form bei einem Druck von etwa 1.01×10^5 Pa (einer Atmosphäre) umfaßt.

8. Verfahren nach Anspruch 1. bei dem der Schritt des Zusammendrückens der Sperrschichtzelle und der Form außerdem den Schritt umfaßt, die Zelle und die Form etwa 30 Minuten lang unter Druck zu halten.

9. Verfahren nach Anspruch 1, bei dem der Schritt des Bereitstellens einer Sperrschichtzelle das Bereitstellen einer Sperrschichtzelle umfaßt, die einen photo-voltaischen Körper hat, der wenigstens eine Schicht eines fluorierten Siliziumlegierungsmaterials einschließt.

10. Verfahren zur Herstellung eines großflächigen photo-voltaischen Moduls, das folgende Schritte aufweist:

Bereitstellen einer Vielzahl von Sperrschichtzellen, wobei jede Zelle ein Bodenelektrodenelement. einen photo-voltaischen Körper, der in elektrischer Verbindung mit der Bodenelektrode angeordnet ist, eine obere Elektrode. die oben auf dem photo-voltaischen Körper angeordnet ist. und wenigstens eine elektrisch leitende Gitterlinie. die in elektrischer Verbindung der oberen Elektrode zugeordnet ist. umfaßt;
Anordnen der Vielzahl von Zellen in elektrisch verbundener Beziehung auf einem Stützelement;
Anordnen einer Schicht eines transparenten. organischen. polymeren Vergußmaterials direkt oben auf der oberen Elektrode und der wenigstens einen Gitterlinie von jeder der Sperrschichtzellen:
Laminieren des Vergußmaterials auf die Zellen, um so eine selbsttragende Baugruppe zu schaffen;
Bereitstellen einer Vielzahl von Prägeformen, wobei jede Form wenigstens ein rillenbildendes Element einschließt;
Ausrichten jeder der Vielzahl von Formen mit jeweils einer der Sperrschichtzellen, so daß sich deren rillenbildendes Element mit wenigstens einem Abschnitt der Länge von einer der wenigstens einen Gitterlinien in Eingriff befindet; und
Zusammendrücken der Formen und der laminierten Baugruppe von Sperrschichtzellen, wodurch die Formen in den Bereichen der Gitterlinien Rillen in der transparenten Vergußschicht bilden, um so integral mit der Schicht des Vergußmaterials ein licht-leitendes optisches Element zu schaffen, um die Schattierung der Gitterlinie zu verringern.

11. Verfahren nach Anspruch 10, bei dem der Schritt des Ausrichtens jeder der Formen mit jeweils einer der Zellen folgendes umfaßt:

Bereitstellen von Ausrichtungsstiften an jeder der Vielzahl von Formen;
Bereitstellen von entsprechenden Löchern für die Ausrichtungsstifte in dem Stützelement; und
Einführen der Ausrichtungsstifte in die Löcher für die Ausrichtungsstifte.

12. Verfahren nach Anspruch 10, bei dem der Schritt des Anordnens der Zellen in elektrisch verbundener Beziehung auf dem Stützelement den Schritt der Verbindung der Zellen untereinander in einer elektrischen Reihenschaltung umfaßt.

13. Verfahren nach Anspruch 10. bei dem der Schritt des Bereitstellens einer Schicht von transparentem Vergußmaterial die Auswahl des Materials aus der Gruppe einschließt, die aus Ethylenvinylacetat, Polytetrafluorethylen. Polyvinylfluorid. Polyurethan und deren Kombinationen besteht.

14. Verfahren nach Anspruch 10. das den weiteren Schritt des Erwärmens der Vielzahl von Formen einschließt.

Revendications

1. Procédé de fabrication d'un dispositif photovoltaïque à effet d'ombrage réduit de l'éclairage incident de lignes de grilles d'un collecteur, ledit procédé comprenant les étapes ci-dessous:

fourniture d'une cellule photovoltaïque, ladite cellule englobant une couche d'électrode de base, un corps photovoltaïque agencé au-dessus de la couche d'électrode de base, une couche d'électrode supérieure agencée au-dessus du corps photovoltaïque et une ligne de grille électroconductrice, collectrice de courant, en communication électrique avec ladite couche d'électrode supérieure;

agencement d'une couche de matériau d'encapsulage polymère organique transparent se prêtant à l'estampage directement au-dessus de la couche d'électrode supérieure;
fourniture d'une plaque d'estampage, ladite plaque englobant au moins un élément de formation de rainures;
alignement de la plaque d'estampage avec la cellule photovoltaïque, de sorte que l'élément de formation de rainures correspondant est aligné avec au moins une partie de la longueur de la ligne de grille et en contact avec la couche de matériau polymère d'encapsulage; et
compression de la plaque d'estampage et de la cellule photovoltaïque de sorte à estamper une rainure dans la couche du matériau d'encapsulage; et
enlèvement de la plaque d'estampage pour produire ainsi une cellule photovoltaïque comportant une rainure faisant partie intégrante de la couche d'encapsulage et alignée avec ladite partie de ladite ligne de grille, ladite rainure dirigeant l'éclairage incident de sorte à l'écarter de la ligne de grille et à réduire ainsi les effets d'ombrage correspondants.

2. Procédé selon la revendication 1, dans lequel l'étape d'agencement d'une couche de matériau d'encapsulage au-dessus de la couche d'électrode supérieure englobe l'étape ultérieure d'application par stratification de ladite couche sur la couche d'électrode supérieure, et dans lequel les étapes d'alignement et de compression sont exécutées après ladite étape de stratification.

3. Procédé selon la revendication 1, dans lequel l'étape d'agencement de ladite couche de matériau polymère organique englobe une étape ultérieure de sélection dudit matériau dans le groupe constitué d'éthylène-acétate de vinyle, de polytétrafluoréthylène, de fluorure de polyvinyle, d'acétate de polyvinyle, de polystyrène, de polyuréthane et de combinaisons correspondantes.

4. Procédé selon la revendication 1, dans lequel ledit matériau polymère est un matériau à réticulation thermique.

5. Procédé selon la revendication 1, englobant l'étape ultérieure de chauffage de ladite plaque d'estampage.

6. Procédé selon la revendication 5, dans lequel l'étape de chauffage de ladite plaque comprend le chauffage à une température d'environ 150°C.

7. Procédé selon la revendication 1, dans lequel l'étape de compression de ladite cellule photovoltaïque et de ladite plaque comprend la compression de ladite cellule et de ladite plaque à une pression d'environ 1.01×10^5 Pa (une atmosphère).

8. Procédé selon la revendication 1, dans lequel l'étape de compression de ladite cellule photovoltaïque et de ladite plaque comprend en outre le maintien de ladite cellule et de ladite plaque sous compression pendant environ 30 minutes.

9. Procédé selon la revendication 1, dans lequel l'étape de fourniture d'une cellule photovoltaïque comprend la fourniture d'une cellule photovoltaïque ayant un corps photovoltaïque englobant au moins une couche d'un matériau d'alliage de silicium fluoré.

10. Procédé de fabrication d'un module photovoltaïque de grande surface, ledit procédé comprenant les étapes ci-dessous:

fourniture de plusieurs cellules photovoltaïques, chaque cellule englobant un élément d'électrode de base, un corps photovoltaïque en communication électrique avec l'électrode de base, une électrode supérieure agencée au-dessus du corps photovoltaïque et au moins une ligne de grille électroconductrice associée avec l'électrode supérieure et en communication électrique avec celle-ci:
agencement desdites plusieurs cellules sur un élément de support dans une relation à interconnexion électrique;
agencement d'une couche de matériau d'encapsulage polymère organique transparent directement au-dessus de l'électrode supérieure et de ladite au moins une ligne de grille de chacune des cellules photovoltaïques;
application par stratification dudit matériau d'encapsulage sur lesdites cellules de sorte à produire un assemblage autoporteur;
fourniture de plusieurs plaques d'estampage, chaque plaque englobant au moins un élément de formation de rainures;
alignement de chacune desdites plusieurs plaques avec une desdites cellules photovoltaïques correspondantes, de sorte que l'élément de formation de rainures correspondant est aligné avec au moins une partie de la longueur de l'une desdites au moins une lignes de grille; et
compression desdites plaques et de l'assemblage stratifié des cellules photovoltaïques, lesdites plaques formant ainsi des rainures dans la couche d'encapsulage transparente dans les régions des lignes de grille, de sorte à fournir un élément optique dirigeant la lumière, faisant partie intégrante de ladite couche de

matériau d'encapsulage réduisant l'effet d'ombrage de la ligne de grille.

11. Procédé selon la revendication 10, dans lequel l'étape d'alignement de chacune desdites plaques avec une desdites cellules correspondantes comprend:

fourniture de goupilles d'alignement sur chacune desdites plusieurs plaques;
agencement de trous de goupille d'alignement correspondants dans ledit élément de support; et
mise en place desdites goupilles d'alignement dans lesdits trous de goupille d'alignement.

12. Procédé selon la revendication 10. dans lequel l'étape d'agencement desdites cellules sur ledit élément de support dans une relation à interconnexion électrique comprend l'étape d'interconnexion desdites cellules dans une relation électrique en série.

13. Procédé selon la revendication 10, dans lequel l'étape de fourniture d'une coucne de matériau d'encapsulage transparent comprend la sélection dudit matériau dans le groupe constitué d'éthylène-acétate de vinyle, de polytétrafluoréthylène, de fluorure de polyvinyle, de polyuréthane et de combinaisons correspondantes.

14. Procédé selon la revendication 10, englobant l'étape ultérieure de chauffage desdites plusieurs plaques.

FIG - 1
PRIOR ART

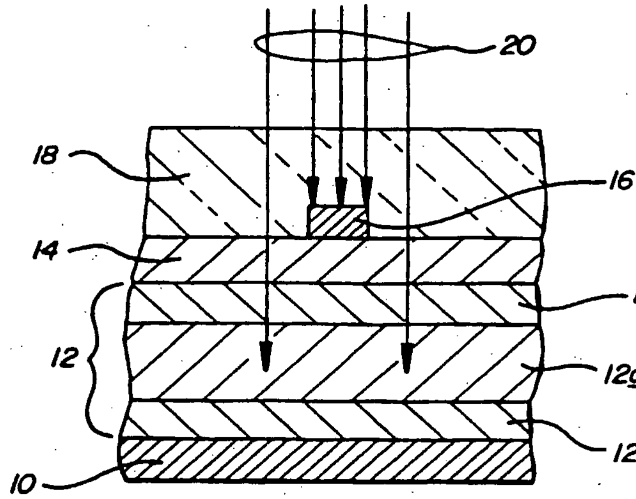


FIG - 2

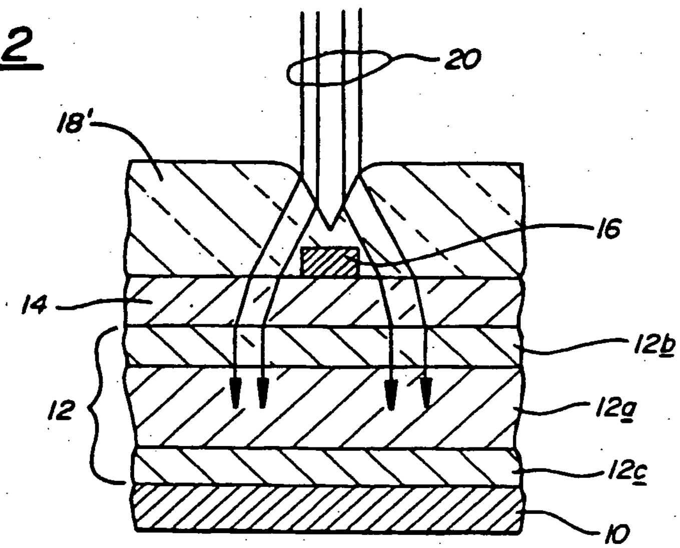
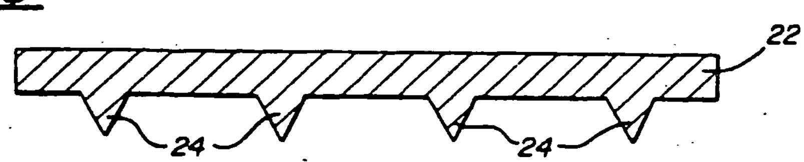


FIG - 3



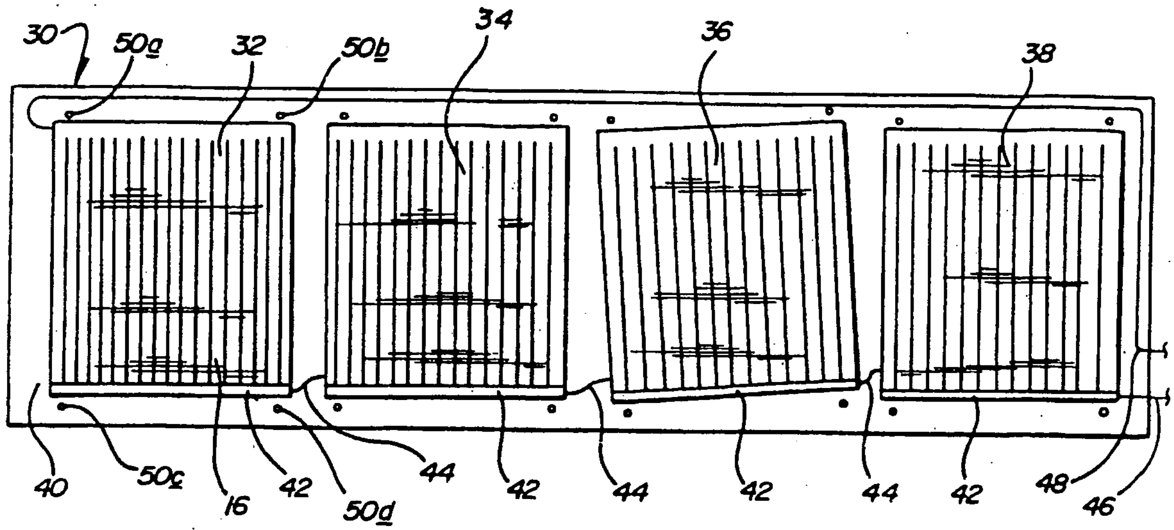


FIG - 4

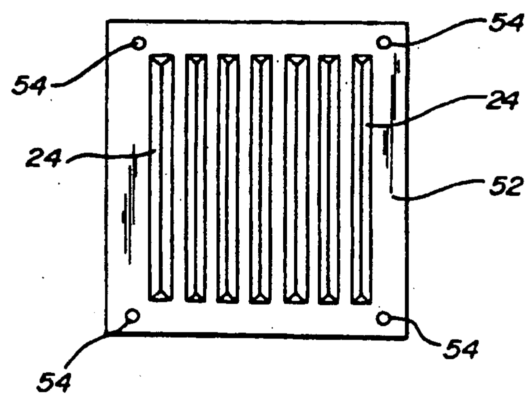


FIG - 5

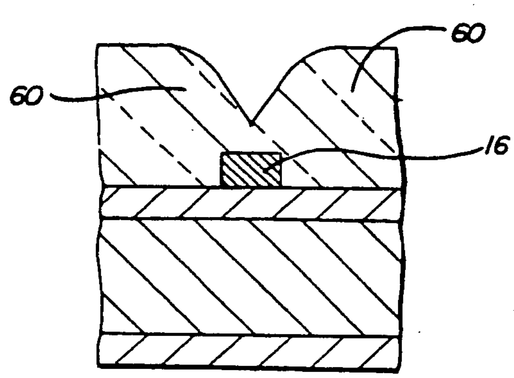


FIG - 6

FIG - 7A

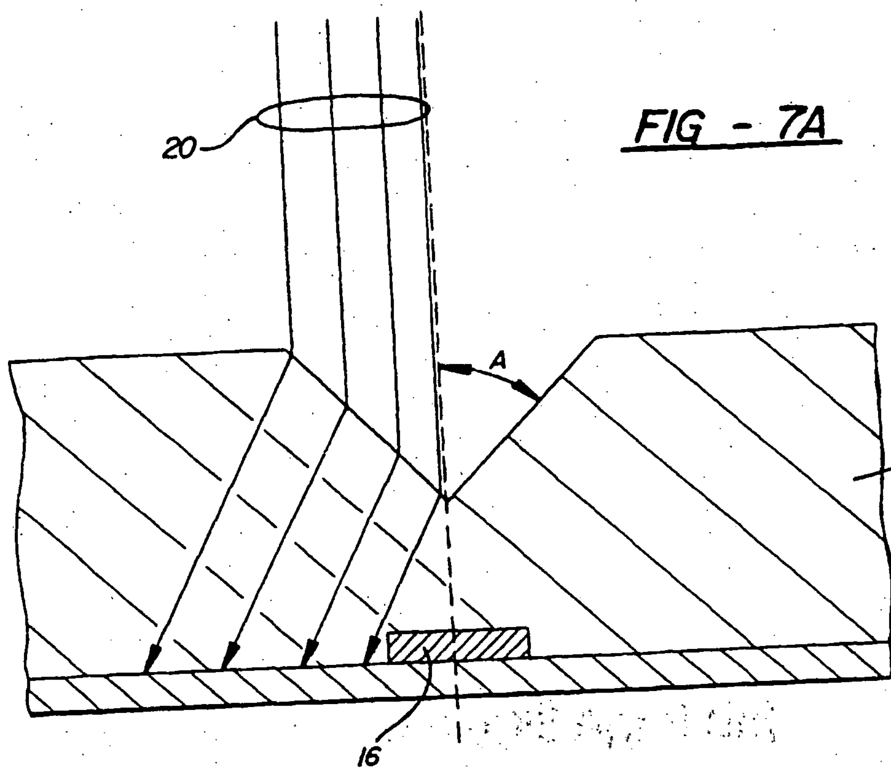


FIG - 7B